Art. XVII.—*Floods on the River Barwon.*

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[Read 8th December, 1881.]

(With Diagram.)

1. It may make this paper more clear to many to state at the outset that the Barwon floods formed the subject of a trial lately at Geelong, where damage was said to have been caused to certain mills by reason of the construction of the railway across the river having raised the level of the flood which occurred in September, 1880. The verdict of the jury was to the effect that negligence, in a legal sense, had been shown in the construction of the railway, and that the flood had been raised, at the mills in question, one foot above the level of a former flood which occurred in 1852. The matter having been so far settled, this paper has been written to elucidate the points of scientific interest in a way that was not possible in a court of justice, where, of course, all technicalities were, as far as possible, avoided in laying the matter before the jury. Some of the evidence sworn to by witnesses in court is evidently incompatible with other evidence, and has had to be rejected by the author; but in doing so, he does not wish to cast the slightest reflection on any witness, as he fully believes each one was actuated with a desire to testify to facts. Mistakes have undoubtedly been made, and this is not surprising, especially in the case of the flood of 1852, which took place twenty-nine years ago. In many cases, perhaps, a little extra information would have served to explain differences; but in others, doubtless, mistakes have been made which render the information useless.

2. Widely different opinions were expressed by professional witnesses on various points. The author is of opinion that some conclusions were drawn after merely a superficial inquiry into a very difficult subject, which many engineers may not have had opportunities of studying. From several years' experience in hydraulic engineering, the author has found that the facts which first attract attention are often misleading, and it is not till an almost exhaustive inquiry has

been instituted and all facts carefully compared, that an engineer is justified in feeling sure that he has proper data to work upon. At sudden contractions, sharp bends, and wherever obstructions occur in the stream, single flood-marks should be accepted with caution. It will be seen further on that much discretion is required in making use of levels obtained at such places.

3. Two or more series of levels were taken to ascertain the relative heights of various points. The datum to which all these have been reduced is mean low-water level of Hobson's Bay, obtained through the railway engineers, it is understood. Several cross-sections of the river were also taken at suitable points. Without these cross-sections, calculations of the quantities of water and velocities at various places could not have been made, nor could the action of the flood have been properly investigated. The omission of this part of the inquiry by some engineers has led to erroneous views having been put forward as to the action of the flood. Some of the data on which calculations have been based are, for convenience, given in a tabular form in an appendix to this paper. The main results of the calculations made by the author are shown in the accompanying diagram, forming a longitudinal section of the portion of the river where the action of the floods has been complicated by the two embankments formed since the great flood of 1852. The upper embankment is the Colac-road causeway, forming the approaches to the iron bridge, also known as the Moorabool-street bridge. The other, a mile and a-half lower down the river, is the railway embankment, which was formed about the year 1875.

4. The author is greatly indebted to Mr. T. B. Muntz, city surveyor of Prahran and a member of this Society, for permission to make use of the cross-sections and of the levels, and much other information collected and arranged by him: also for the loan of a plan* of the river showing the course of the flood of 1880. The author has also to acknowledge the receipt of much valuable information from Mr. Robert Watson, the well-known railway engineer; and from Mr. W. C. Kernot, of the University.

5. The catchment basin of the River Barwon, with its tributaries—the Moorabool, Yarrowee (or Leigh), and several small creeks—is estimated to have an area of about 1500

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* The plan has not been printed.

square miles. From the junction of the Barwon and Moorabool Rivers at Fyansford, about four miles above Geelong, no stream of any size falls into the river till immediately below the existing railway embankment, where the Waurn Ponds Creek joins it. This creek enters the valley of the Barwon above the embankment, in which an opening was left so that the waters of the creek might flow on in their natural channel. Five or six miles below Geelong the Barwon discharges into Lake Connewarre, which is connected with the sea. The influence of the tides extends as far as Geelong, but is very slight, excepting, perhaps, as some say, during the prevalence of strong southerly winds.

6. There was a great flood in the Barwon in May, 1852, when there appears to have been no artificial obstruction of importance (that is, compared with existing obstructions) across the river. Where the iron bridge now is (C.S. No. 6), connecting Moorabool-street in Geelong with the Colac-road on the other side of the river, there was a wooden pile bridge, which was washed away by that flood; but the obstruction caused at this place was confined, as far as the author can ascertain, to the ordinary river channel; there were no raised approaches as at present. The iron bridge was afterwards erected in place of the wooden bridge. About one and a-half miles below this, the railway was, in 1875, constructed across the valley, with a large bridge over the ordinary bed of the River Barwon, and a smaller bridge over the Waurn Ponds Creek. At a gorge (C.S. No. 1), one and a-half miles further down—a point of considerable importance in this inquiry—a tannery was erected a few years after the flood of 1852, causing, as far as can be ascertained, only a slight obstruction in the flood of 1880.

7. Though the River Barwon when confined to its ordinary bed (200 to 300 feet only in width) may present few difficulties, such is not the case when it is in flood. At such a time there are here and there obstructions to the flow of the water, while above and below these the water spreads out into what, in a bird's-eye view, would appear as lakes, but the water generally flows through these in a broad stream, which in one place is nearly a mile in width. Owing to the absence of any length of moderately uniform channel, it would not be easy to calculate accurately the volume of water flowing past any point in a flood, even if the level of the water remained constant for a sufficient time to note its main features. When, however, as in this case, a few flood-

marks, obtained long after the water has subsided (which marks may have been caused at various times during the flood), form the only data, the case becomes very complicated. The levels of the actual flood, as well as can be ascertained, are shown in the accompanying diagram by black lines, the shaded line representing the midstream section.

8. The volume of water flowing down the river during the flood of 1880 is found by the author to have been as follows: —At two p.m. on Sunday, 12th September, when it is said the flood level at the mills reached its highest, probably a less quantity than 65,000 cubic feet per second was flowing off. The level at the mills is said to have remained constant till five p.m., when it is calculated the quantity of water coming down the Barwon was 69,000 cubic feet per second —67,000 under the iron bridge and 2000 over the Colac-road; this was the quantity flowing through the railway bridges at five p.m. It is said that the flood level at the mills fell after five p.m.; but it must have gone down very slowly, since the next morning it had decreased nine inches only; it is also said that the flood some miles up the river, as well as at the gorge, one and a-half miles below the railway embankment, was not at its greatest height till about eleven p.m. All this time the bank must have gone on cutting away; and the author estimates that 600 square feet of waterway were added during the six hours from five to eleven p.m., which would have denoted a largely increased discharge, but for the fact of the water level above the embankment falling; this in turn gave a larger difference of level at the iron bridge, allowing the increased volume of flood water to come down the river without raising the level on the upper side of that bridge. By equating the quantities, it is calculated that about 2000 cubic feet per second was the additional quantity of water flowing down the Barwon at eleven p.m., making the total discharge then 71,000 cubic feet per second.

9. Some water would also without doubt be coming down the Waurn Ponds Creek, though it does not seem to have been observed. It may safely be assumed that it was being carried off by the breach in the railway embankment (70 to 90 feet in length) which had occurred near what is called the Marshalltown crossing, about half a mile south of the Waurn Ponds bridge. As, however, this water would have to pass through the gorge (C.S. No. 1) one and a-half miles below the railway, it is necessary to form some estimate of the quantity. The area drained by the creek being

taken at 40 square miles, the flood discharge would probably be 4000 cubic feet per second; but the catchment area being so much smaller than that of the Barwon, the flood from the creek would have begun to subside long before that from the Barwon was at its height. The author considers that 2000 cubic feet should be added for the discharge of the Waurn Ponds Creek when the flood coming down the Barwon was at its height (at eleven p.m.). This would make the quantity passing at that time through the gorge (C.S. No. 1) 73,000 cubic feet per second.

10. The water impounded by the railway embankment, when it began to flow off, would also pass through this gorge; but, except for the cutting away of the banks, the impounded water would not, under the conditions of the case, flow off till the water level below the embankment had begun to fall. As regards the effect of the cutting away of the bank in this case, it is allowed for in the calculation of the additional water (2000 cubic feet) coming down at eleven p.m. In any case, the increase due to the impounded water flowing off could have been but very small. Taking the area at 36,000,000 square feet, and the fall in the water level at nine inches by the next morning (say, in twelve hours), the mean quantity would be only 625 cubic feet per second; but as up till eleven p.m. the fall is estimated by the author at only $\frac{1}{10}$-foot, or a little more, the increase was, in the first six hours, less than 200 cubic feet per second. After eleven p.m., as the flood was decreasing, the additional quantity of the impounded water flowing off (a little over 1000 cubic feet per second on the average of the six hours, less at first and more afterwards) did not affect the maximum discharge at the gorge (C.S. No. 1). Evidently, when the flood level was falling, less water must have been flowing past this point, unless some special cause were at work to produce any other result.

11. Having ascertained the volume of the flood, it is possible to inquire into its action at various important points. The water was flowing with a velocity of nearly 9 feet per second through the two openings of the iron bridge, aggregating about 400 feet in length, into a basin of comparatively still water at least 1600 feet wide; the stream was, in fact, confined at first to a width of 400 feet only out of the 1600 feet width of the river; but its width rapidly increased as it advanced, and its velocity was retarded. In consequence of the contracted waterway, the set of the

stream was against the north bank of the river, overflowing in a continuous wave* the ground where the mills, which suffered damage by the flood, were situated. At C.S. No. 5, taken opposite the mills, it is estimated that only one-third of the flat on the south side of the ordinary river channel was in the current. The level of the water was on the north side of the river higher than on the south side, the difference being considerable at first, and decreasing as the velocity of the water became more nearly uniform on both sides.

12. Below the railway the same result followed from the contraction of the waterway, though to a much greater extent than at the iron bridge, owing to the greater contraction. The lineal waterway of both railway bridges was a little less than 600 feet originally, but was increased during the flood to a little more than 1050 feet, out of a width of 4000 feet for the whole river, measured *along* the railway; taken square with the stream about the same proportion would be found, but it is difficult to give the exact figures. The stream immediately below the railway thus varied from less than one-sixth to about one-fourth of the width of the river. The consequence was a great difference in the flood levels here. Those obtained from Mr. Muntz show that at one place, *in the stream,* the water rose to R.L. 20·89; while at another place, *out of the stream,* the water did not rise higher than R.L. 18·53. The levels obtained from the engineers who gave evidence for the Railway Department show a level of 20·42 at one place (Haworth's tannery) and only 18·77 at another place (Corrigan's house). These differences of level are very important, and will be referred to again.

13. At C.S. No. 3, a short distance further down, where the stream was again forced over by the railway embankment in a wave* to the north side of the river, the current was confined to about 1400 feet out of a total width of the river at that point of 2500 feet. Some distance below C.S. No. 2, owing to the bend in the river, the set of the stream was against the south bank. A little above the gorge (C.S. No. 1), one and a-half miles below the railway, the water was observed to flow with great force between some outhouses there and the bank, and after dashing against the wall of the tannery to pour down alongside of it into the main stream, with a fall of one foot in a length of

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* Shown in the diagram by a whole unshaded black line.

about 150 feet.* How the water behaved at the gorge itself is not accurately known, though one witness said it seemed to be much lower in the middle of the river. It was at first thought that the level (16·06) obtained from a well-defined flood-mark made in 1880 in one of the rooms of the tannery there, represented fairly the level of the water across the gorge; but further investigation throws much doubt on this. The mark being at a sudden contraction, and at a bend in the river, the level, *as a mean for the section*, should (as before remarked) be accepted with caution. Owing to the stream being confined at this place to the south side of the river, there was probably as great a difference of level in the flood on the two sides of the river as below the railway embankment (see last par.). After much careful consideration of the point, the author is of opinion that R.L. 15·00 is more likely to have been the average level of the section than 16·06. Calculations of the 1852 flood support this view.

14. A few words regarding the method of calculation adopted may be useful to those wishing to follow up the subject, or to apply the same method to other cases. The ordinary rules and formulæ are not strictly applicable to such irregular channels as the portion of the Barwon River dealt with in this paper. The formulæ given in manuals on hydraulics for irregular channels are, however, generally so complicated that often, rather than use them, one prefers to obtain the results by a series of approximations with the ordinary formulæ. In many cases, the results obtained by either method must be looked upon as mere approximations; but it is better to accept them as such, than, because exact results are not obtainable, remain in total ignorance of the quantity of water to be dealt with, its velocity, and other conditions of motion.

15. In this case, the first thing done was to sketch on the plan the probable course of the stream, and to take the sectional areas of such portions only of the river as would, under the special conditions of the case, be in the stream. Next it was assumed generally that the velocity varied inversely with the area in the stream. Then, at each of the cross sections, the information required has been calculated from the known data on the supposition that the section is that of a uniform open channel. The last

* Shown in the diagram by a dotted black line.

two propositions are not strictly true unless the changes from point to point are very gradual; but they sometimes form the only means of arriving at even an approximate result. An additional loss of head, beyond what the regular calculations give, has been allowed, according to circumstances, when a sudden reduction of velocity takes place; since, in irregular channels where side currents and eddies are formed, such loss always takes place. The loss of head at each contraction is shown on the diagram; the fall appears as a step where the contraction is great and sudden, as a wave or double curve where the contraction is gradual. The fall or loss of head increases as the *difference* of velocity increases at any given point. The formulæ adopted for the calculations were those ordinarily used in hydraulic investigations. Their application in the manner above described explains some of the difficulties of this case; while the neglect of such calculations appears to have led more than one professional witness to erroneous conclusions.

16. One great difficulty in the case was the following:—The actual level of the flood at one point below the embankment was about 3 feet above the level of the floor of one of the mills, and yet engineers gave evidence to the effect that the flood would have risen a few inches only on the floor of the mill, had the railway embankment not been in existence. A jury might well be excused for preferring the fact to the theory; still the paradox is capable of explanation, though it must needs be a somewhat lengthy one. Omitting the influence of wind in an open channel or reservoir, water is motionless so long as the surface remains level, but so soon as a difference of level takes place, motion commences, the water flowing from the place of higher to that of lower level. The greater the difference of level, the more rapid the motion; or, in other words, the greater the velocity of flow; and conversely, the greater the velocity, the greater the difference of level must necessarily be. Now, in any channel of given width, the depth of water and the slope of its surface adjust themselves to the volume of water flowing down it. If the width of the channel be reduced at any part, it is necessary in order that the same quantity of water may pass through the contracted part, that both the depth and velocity should be increased in one of two ways—(1) if the contracted part be uniform in section and slope for such a length that the depth of water would remain uniform, the increased velocity would be obtained by the increase of depth alone; but (2)

if the contracted part of the channel be short enough to allow the surface slope to vary, the depth would increase to such an extent only as would discharge the same quantity of water with increased surface slope and depth combined.

17. Applying these principles to the case of a stream confined to one portion of a channel, the necessity for a rise in the surface level becomes apparent. The great difference of level below the railway embankment, already mentioned (see par. 12), is an example of this. The calculations made at each contraction give the same results, which are shown in the diagram. As a general rule the cross-section of any stream shows a horizontal line for the surface of the water only when the depth and velocity right across are uniform, or nearly so. When one part of a channel is much deeper than the rest, and the velocity of the water in that part is much greater than in other parts, the level of the water is raised there, so that the surface line is uneven, and not level, as often supposed. When the stream is confined to only a portion of the channel, the rest being still or back-water, the irregularity of the surface line is greatest. This is exemplified by the flood levels obtained immediately below the railway embankment (see par. 12). This effect may be often observed when pouring water from a jug into a basin; it may be seen also in some of the large drains in Melbourne, at the bottom of Elizabeth-street for instance. Where the velocity of any stream is greatest, the surface is generally higher than elsewhere on the same cross-section.

18. Calculations made on the foregoing principles in connection with the flood of 1880 having given results as nearly in accordance with the facts as could be expected, considering the conditions of the case, other calculations were made to show what the levels of the flood would have been, had the two embankments above alluded to not been in existence; that is, if it had occurred in 1852, when the river was comparatively free from obstruction. The results obtained by the author are shown on the diagram by the shaded red line. The starting point is R.L. 15·00 at C.S. No. 1 (see par. 13), and the following are the differences of level worked out:—Immediately above the railway embankment, the water would have been about 4¼* feet lower; opposite the mills (C.S. No. 5), nearly 3¾† feet lower; and just

* R.L. 21·20—R.L. 16·90 = 4·30 feet.

† R.L. 21·50—R.L. 17.80 = 3·70 feet. Inside the mills the water would have been upwards of 4 feet lower.

above the iron bridge nearly $4\frac{3}{4}$* feet lower; further up the river the differences would gradually become less and less. Had the river been as before 1875—that is, the Colac-road causeway in existence, but not the railway embankment—the author calculates the water would have been as shown by the dotted red line, viz.:—In the Victorian Woollen Mills, more than $3\frac{1}{2}$† feet lower than it actually was, and above the iron bridge $1\frac{3}{4}$‡ feet lower, and less further up the river.

19. Attempts have been made to learn the facts of the flood of 1852, but owing to the uncertainty regarding the levels, this has been a most difficult task. The levels which the engineers appearing on behalf of the railway department in the late trial seem to have accepted, would, without modification, give a result which the author feels compelled to reject. Owing to the great slope between the extreme points, or even reducing it by nine inches at an intermediate point to agree with other evidence produced at the trial, the quantity of water would be about 150,000 cubic feet per second, which could not in itself, perhaps, be objected to; but when it is found that for this quantity of water to escape at C.S. No. 1, the level there would be lower than half that quantity of water attained in 1880, it is clear that it must be wrong, unless it can be shown that material alterations have been made in the river below, sufficient to account for this difference. As far as can be ascertained, very little obstruction has been caused at a level that would affect the above results.

20. After numerous failures to arrive at a satisfactory result, the author has obtained one that may be accepted as fairly within the bounds of probability. Above the iron bridge, a flood level—which the author is informed was taken a few months after the flood occurred (or, nearly 29 years ago)—has been adopted in place of the high level (22·80) lately obtained at the Albion Mills by the railway engineers. A little latitude has also been allowed to the other levels, which, considering the number of years since the flood occurred, and the uncertainty of the marks, can scarcely be objected to. On such data the author's calculations make the flood discharge of 1852 to have been about 120,000 cubic feet per second. The author is, however, strongly of opinion that this is more than the actual quantity, but as it is not convenient to enquire for further

* R.L. 23·05—R.L. 18·35 = 4·70 feet.
† R.L. 21·90—R.L. 18·30 = 3·60 feet.
‡ R.L. 23·05—R.L. 21·30 = 1·75 feet.

data, the 120,000 cubic feet per second may be accepted for the purpose of this paper. The mid-stream section, as worked out by the author, is shown in the diagram by the shaded blue line.

21. The last series of calculations made were with a view to show what levels another flood similar to that of 1852 would give under the existing condition of the river. The result is shown by the dotted blue line, which immediately above the railway embankment rises 2½ feet above the flood of 1880; that is, if a flood similar to that of 1852 were to occur now, it would go over the top of the embankment some distance south of the Waurn Ponds bridge, unless the banks cut away as they did in 1880. It is not improbable that the flood would rise still higher, since the increase at and above C.S. No. 1, due to the stream being confined to a portion of the river, is not (considering the section of the actual flood of 1880) fully allowed for. The rise that would be caused is not calculable owing to the direction of the mid-stream being so complicated by the obstructions at the railway embankment. If this is the result given by 120,000 cubic feet per second, it may be left to those who are interested in the matter to decide what would happen if the volume were 150,000 cubic feet per second, as the exact levels given by the railway engineers would require.

22. The deductions from the foregoing investigation are instructive. The railway engineers asserted at the trial that the provision, so far as length of waterway is concerned, for the highest known flood is ample; but the author can only suppose that they omitted to inquire into the volume of water to be dealt with. Notwithstanding the failure of the embankment across the Barwon, and the damage caused by the late flood, not only to private property, but also to the railway itself, the only modification which it is understood the railway engineers now agree to be necessary is to raise the embankment and bridges a few feet. This is in consequence of the flood level having been taken too low at first; it is now said that an error of more than 3 feet in the flood level of 1852 was made when inquiries were instituted preparatory to the construction of the railway. Considering all the facts of the case, it is difficult to understand how simply increasing the headway for floods will, without lengthening the waterway, remove all danger. Another flood similar to that of 1880 would, in the present condition of things, be only a shade less

disastrous than that was. The water would rise to within a very little of the level it then attained; for it must be remembered that it only rose to the levels shown by most of the flood-marks after the bank had cut away to nearly the extent of the existing waterway. The mean velocity of the water flowing through the Barwon bridge (obstructed by struts, &c.) would, in another similar flood, be about $5\frac{1}{2}$ feet per second; while, through the Waurn Ponds bridge it would be more than 7 feet per second. Under these circumstances, can it be expected that the banks, in their present unprotected state, would not again cut away? It may well be questioned whether anything short of masonry abutments would be perfectly safe in case of another flood similar to that of 1880; certainly nothing less could withstand another flood similar to that of 1852. Supposing, however, the banks to be adequately protected, there would still remain the risk of a serious scour under both bridges. In the author's opinion, it is necessary considerably to lengthen the waterway at the same time that the headway under the bridges is increased, before the line across the Barwon can be considered safe.

23. This is a subject, it may be remarked, which does not require an engineer experienced in railway construction to decide; it is especially one for a hydraulic engineer. Considerations of the waterway apply as well to a bridge for a common road as to one for a railway. Flood waters and large volumes of water in motion generally are not to be controlled, except by proper methods, based on sound hydraulic principles. General rules, the result of long experience in all parts of the world, are laid down in standard works on this branch of engineering; and when such, accepted and constantly used by the heads of the profession, are set on one side, good reasons for so doing should be forthcoming. Practice is a most valuable guide; but in order that it may be turned to the best account, it requires to be supplemented by theory, or a thorough knowledge of the principles of construction and of the sciences on which engineering depends. In hydraulic works, an engineer requires to know, as nearly as possible, the volume of water he has to deal with, its velocity when in motion, and such other information as, under the special conditions of the case, he is able to obtain. If exact results are unattainable, an approximation is better than total ignorance on these points; though the more uncertain the results, the greater the margin for safety

to be allowed, as a rule. Without some information on the above-mentioned points, no engineer can feel sure that any works which interfere with a channel are safe. It is not enough in such a case to know merely the highest flood level; if that is all the knowledge obtainable, a channel should always be kept as free as possible from obstruction. And in questions of this nature, it must not be overlooked that where a river in flood overflows its ordinary banks, the channel to be considered is not merely the summer bed of the river, but the whole width in which there is a downward current. If there is not intended to be any contraction of the waterway, the knowledge of the highest flood level might often suffice; though it would be always more satisfactory to ascertain, if possible, the flood discharge as well as the flood level. Many of these remarks may appear very commonplace, but that they are not wholly unnecessary is clear from the points alluded to having been overlooked in the case of an important river like the Barwon.

24. In conclusion, the author desires to state his decided conviction that the whole of the trouble and expense (in the late trial) resulting from the flood of September, 1880, arose from the neglect of the foregoing considerations when designing the railway across the Barwon. Had a proper inquiry into the action of the flood of 1852 been made before the line was constructed, the iron bridge on the Colac-road would not have been taken as the sole guide for the waterway to be given to the railway bridge over the same river, as it was admitted at the trial was done. It may be further remarked that the unfavourable conditions of the site fixed upon for the railway bridge (contrasted with those of the iron bridge site) were not properly allowed for. The iron bridge has an unobstructed waterway with a clear channel below, but the railway bridge has neither of these advantages. Fortunately, however, other arrangements, without being designed for such a contingency, in a measure counteracted some of the errors that were made. The Barwon bridge was evidently intended to carry off the flood waters of the River Barwon, and the Waurn Ponds bridge those of the Waurn Ponds creek; but, in reality, in September, 1880, the latter bridge served the purpose of a safety-valve to the Barwon; and when the flood was at its height, it (with the adjoining gaps in the embankment) discharged about the same quantity of water as the Barwon bridge itself. Certainly, the cutting away of the railway

embankment in several places prevented the damage to private property above the embankment being more serious than it was. The fact that no train dashed into one of the gaps in the embankment is a matter of congratulation; there would have been more than a possibility of such an occurrence had the flood happened on any day but Sunday; and it ought not to be overlooked that, under present conditions, there will again be the same risk when the next flood takes place. Under these circumstances, the subject possesses an importance that should secure a remedy for the existing defects.

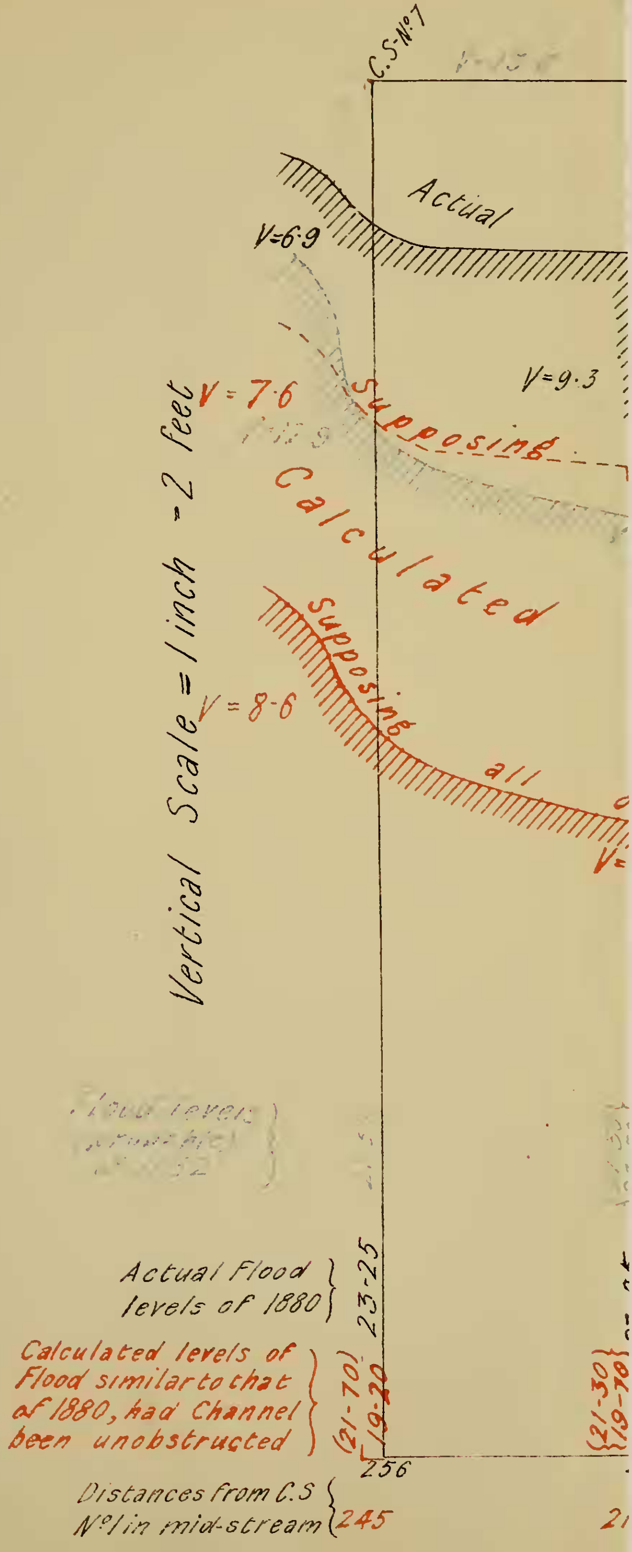
See Appendix, on next page.

APPENDIX—*Giving some of the Data in connection with the Floods on the River Barwon in* 1852 *and* 1880, *on which are based the Calculations referred to in the foregoing Paragraphs.*

Cross Section No.	Distances above C.S. No. 1, measuring— Along Ordinary Summer Channel.	By the Stream when in Flood. Unobstructed, as in 1852.	By the Stream when in Flood. Obstructed, as in 1880.	Reduced Levels* in Mid-stream of Flood of 1880.	Width of Stream at given Levels. Possible, if Obstructions did not exist, as in 1852.	Width of Stream at given Levels. Estimated as effective in the Flood of 1880.	Sectional Areas of Stream at given Levels and Widths. Full Width, unobstructed, as in 1852.	Sectional Areas of Stream at given Levels and Widths. Estimated as effective in 1880.	Percentage of unobstructed area effective in 1880.	Remarks.
	Chains.	Chains.	Chains.	Feet.	Feet.	Feet.	Supfl. Feet.	Superficial Feet.		
1	..	..	..	15·00 / 17·00†	750	640	9,960	9,670	97	A tannery, built since the flood of 1852, obstructs slightly the flood waterway at this point. The higher level (17·00) was a little above the gorge. Widths and areas of stream refer to R.L. 15·00.
2	41	41	41	17·60	2,200	?	23,000	?	..	Flood-mark on north bank was higher than the level here given for mid-stream, which in this case is somewhat uncertain. Width and area of stream are also uncertain.
3	92	86	86	18·70	2,500	1,400	24,800	15,300	62	Section taken at a narrow part of river, a little below railway embankment. On north bank flood-mark was much higher, and on south bank lower, than in mid-stream.
4	124	106	110	19·70 / 21·20†	4 000	600 originally, increased during flood to 1050	‡ 44,000	§ 9000 originally, increased during flood to 13,900	14 to 26	Section alongside railway embankment, but not crossing the river at right-angles to stream. The areas here given cannot be fairly compared with those of the other sections, owing to obstructions in the waterway of bridges.§
5	206	192	194	21·50	3,000 1,400	1,150 700	33,200 6,300	14,500 3,150	45	South side of river and main channel. North side of river (about R.L. 17·00) overflowed in both floods.
6	242	218	228	21·90 / 23·05†	1,600	400	17,600	7,660	44	Section taken alongside the Colac-road causeway.
7	270	245	256	23·25 / 23·85†	500	500	10,130	10,130	100	Levels are somewhat uncertain at this section, which was taken at a gorge, where there are no well-defined marks.

* Above mean low-water level of Hobson's Bay. † These are the higher levels, where there was a sudden fall in the stream. Width and areas refer to the lower levels only. ‡ No. 4 does not give a fair sectional area of river, owing to the section not being at right-angles to the stream. § See note A (over leaf).

Diagram



Note–Datum is mean low-wa